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Research

Death and long-term disability after gun injury: a cohort analysis

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Abstract

Background: Gun injury accounts for substantial acute mortality worldwide and many others survive with lingering disabilities. We investigated whether additional health losses beyond mortality can also arise for patients who survive with long-term disability.

Methods: We conducted a population-based individual patient analysis of adults injured by firearms who had received emergency medical care in Ontario, Canada, from Apr. 1, 2002, to Apr. 1, 2019. Longitudinal cohort analyses were evaluated through deterministic linkages of individual electronic patient files. The primary outcome was death or subsequent application for long-term disability in the years after hospital discharge.

Results: In total, 8313 patients were injured from firearms, of which 3020 were injured from intentional incidents and 5293 were injured from unintentional incidents. A total of 2657 (88.0%) patients with intentional gun injury and 5089 (96.1%) patients with unintentional gun injury survived initial injuries. After a mean 7.75 years of follow-up, patients surviving intentional injuries had a disability rate twice as high as patients surviving unintentional injuries (19.7% v. 10.1%, $p < 0.001$), equivalent to a hazard ratio of 2.01 (95% confidence interval 1.80–2.25). The higher risk of long-term disability for survivors after intentional gun injury was not explained by demographic characteristics, extended to survivors treated and released from the emergency department, and was observed regardless of whether the incident was self-inflicted or from interpersonal assault. Half of the disability cases were identified after the first year. Additional predictors of long-term disability included a lower socioeconomic status, an urban home location, arrival by ambulance transport, a history of mental illness and a diagnosis of substance use disorder.

Interpretation: Our study shows that gun death statistics underestimate the extent of health losses from long-term disability, particularly for those with intentional injuries. Additional and sustainable follow-up medical care might improve patient outcomes.

Guns can be useful for hunting excursions, sport shooting and self-defence. Canadians living in wilderness regions rely on guns for securing food and protecting themselves against animal attacks.[1] However, a large downside of guns is the risk of injury. In Canada, mortality from gun injuries amounts to 800 total deaths annually, equivalent to a rate of 23 deaths per million per year.[2] An estimated 700 fewer Canadians would die from gun injury each year if per capita mortality rates in Canada matched those in the United Kingdom.[3,4] Some countries have a higher mortality from gun injuries, including the United States with a rate of about 200 deaths per million population per year.[5]

Many people survive gun injury, which means mortality rates may underestimate the total health losses.[6] For example, some patients with through-and-through brain injuries (i.e., from a bullet that has passed through leaving entry and exit wounds) stay alive but reside in long-term care institutions.[7] The intensity of pain or neurologic deficits associated with gun injury can be severe and lasting.[8] Up to half of those with gun injury show anxiety, depression or other signs of stress while in hospital.[9,10] Disfigurement can lead to further complications.[11] Conversely, some patients view survivorship as a source of personal pride, community prestige or divine intervention.[12,13] However, aside from reports after military combat, rigorous studies are near-silent about long-term prognosis and instead focus on acute care survival.[14–16]

The aim of this study was to examine whether the risks of death and long-term disability are substantial after gun injury, contrary to the rapid recoveries depicted in some action movies. Moreover, we hypothesized that intentional gun injury, relative to unintentional gun injury, would lead to a greater burden of long-term disability because of the differences in wound anatomy, patient characteristics, injury circumstances, trauma severity, counterfactual reasoning, psychological outrage and community supports.[17–19] Herein we explore this distinction and apply population-wide health care databases to examine long-term outcomes for patients who survive gun injury.

Competing interests: None declared.

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Methods

Setting

Ontario is Canada's most populous province, and had a population of 13 069 182 in 2010 (study midpoint) distributed over 1 074 845 km^2 of land area (urban and rural).[20,21] Health services data could be analyzed through individually linked population-based databases at ICES.[22–27] Emergency care was universally available with no user fees for all 178 hospitals in the province and the data could be tracked through encrypted linked ICES databases.[24,28,29] Prevailing laws during the study period (Apr. 1, 2002, to Apr. 1, 2019) included a mandate for medical reporting of all patients who experienced gun injury.[30] Diverse disability programs were available for adults older than 18 years, based on physician assessments that were included in ICES databases.[31] The population average incidence of disability is about 7 per 1000 people annually in this region.[32]

Gun injury

We identified adults aged 16 years or older injured by firearms and who had received emergency medical care between Apr. 1, 2002, and Apr. 1, 2019. These dates included all the years for which data were available in ICES databases and a minimum 1-year follow-up for nearly every patient. Past studies indicate that ICES databases are comprehensive (covering > 99% of emergency departments), connected (linkage rates > 95%) and consistent (diagnostic reliability > 90% compared with chart abstraction).[25,33,34] Diagnoses were based on the International Classification of Diseases as validated and used in past studies (codes W32–34, X72–74, X93–95 and Y22–24).[35–39] We excluded those dead at the scene, those living outside of Ontario, those lacking a valid health card number and youth younger than 16 years (eligibility age for disability support). Patients with more than 1 injury were analyzed by first presentation to avoid statistical artifacts from trauma recidivism.[40]

Additional characteristics

Data on patient age (years), sex (binary), socioeconomic status (quintile) and home location (urban, rural) were based on linked demographic databases.[26,41,42] Additional databases identified incident time (year, season, hour), firearm type (hand gun, long gun, uncertain) and whether the patient arrived by ambulance (air or ground).[29] Intentional injuries (self-inflicted, assault) were defined by diagnostic codes with uncertain cases presumed unintentional.[43,44] We further searched outpatient databases in the prior year to identify earlier psychiatric illnesses and diagnosis of substance use disorder.[45] General health care use indicators in the prior year also included total hospital admissions, emergency visits and outpatient contacts as proxies for comorbidity.[46,47]

Acute care

We examined short-term clinical outcomes for secondary descriptive analyses to corroborate past studies.[18,48–50] Hospital mortality included patients who died in the emergency department, during initial hospital admission or after transfer to a specialized trauma centre.[51] Hospital length of stay indicated the total time in days from arrival in the emergency department to death, discharge or departure (including patients who left against medical advice).[52] The number of operations, use of transfusion products and days in intensive care were identified, taking into account those who had none. The available ICES databases lacked information on race, injury circumstances, bullet calibre, vital signs, imaging scans, functional status, formal education and criminal records.[53]

Primary outcome

The primary outcome was subsequent death or long-term disability (i.e., submission of a new disability support application) for patients who survived initial injury. We considered disability as the dominant outcome along with death as a competing risk (each component also tested in secondary analysis). Such disability support applications included a medical report (Health Status Report, Activities of Daily Living Index, Special Necessities Benefit Form) and involved the patient's physician. In turn, the submission of a medical report allowed tracking of applications using Ontario Health Insurance Plan codes (K050–K054).[54,55] The available databases lacked information on social supports and financial programs accessed by patients.

We defined disability as the submission of a new disability support application because the document was available, measurable, authenticated and incorporated the patient's perspective.[55] These techniques have been validated in past research yet can undercount disability because of patients who are reluctant to complain or hesitate to file a claim.[56] We defined the date of disability by the submission of the application because this time was available, objective and served as a marker for the realization that full recovery might not occur. The available databases did not contain information on the reasons for disability, supports received or how it directly connected to the original gun injury.

Statistical analysis

In our primary comparison, we tested whether the risk of disability in the years following gun injury is higher for those with intentional injuries compared with those with unintentional injuries. We defined the follow-up interval as starting on the day of hospital departure and included only those who survived initial injuries. We used unadjusted cumulative incidence curves to evaluate survivors for death or disability during the decade following injury.[57] We further examined the relative risk of death and disability for the full cohort of survivors before and after adjusting for additional measured baseline characteristics using the Fine and Gray model of competing risks (subdistributional hazard ratios used as the estimate of relative risks).[58–61] No data imputation methods were used.

Ethics approval

The study protocol was approved by the Sunnybrook Research Ethics Board, including a waiver for direct individual patient consent.

Results

In total, 8313 individuals were injured by firearms and received emergency medical care during the 17-year study period. Of the total injuries, 63.7% were unintentional injuries and 36.3% were intentional injuries (Table 1). Both groups mainly consisted of men younger than 30 years, and the individuals were widely distributed across socioeconomic status quintiles. Patients with intentional injuries, relative to those with unintentional injuries, tended to live in a city, have an uncertain weapon type and arrive by ambulance transport. Injuries occurring on the weekends were frequent in both groups and a nighttime incident was disproportionately frequent for those with intentional injuries (Appendix 1A, available at www.cmajopen.ca/content/8/3/E469/suppl/DC1). A minority in both groups had a past hospital admission or a past mental health diagnosis.

Acute care outcomes

A total of 2430 patients were admitted to hospital (Table 2). Among those admitted to hospital, about two-thirds required a surgical procedure, one-third required critical care, and a quarter of those admitted to hospital received transfusion products. In total, the cohort accounted for 6191 days in critical care and 24 577 days of hospital stay.

The general profile of short-term acute hospital care suggested a greater severity of injury for patients with intentional incidents compared with those with unintentional incidents, as measured by hospital admission rates, surgical procedures, critical care, blood transfusions, mean days in hospital and risk of acute death (Table 2). A total of 2657 patients with intentional gun injury and 5089 patients with unintentional gun injury survived initial injuries.

Subsequent risk of disability

The 7746 total survivors accounted for 60 098.6 patient-years of follow-up (mean 7.75 yr). Patients surviving intentional gun injury accounted for 584 subsequent cases of disability over 17 669.4 patient-years of follow-up (mean 6.65 yr), equal to an incidence of 33 per 1000 patients annually. Patients surviving unintentional gun injury accounted for 639 subsequent cases of disability over 42 429.2 patient-years of follow-up (mean 8.34 yr), equal to an incidence of 15 per 1000 patients annually. Taken together, intentional gun injury was associated with an increased risk of subsequent disability relative to unintentional gun injury (disability rate 19.7% v. 10.1%, respectively, $p < 0.001$; hazard ratio [HR] 2.01, 95% confidence interval [CI] 1.80–2.2.5). For both groups, half the disability cases appeared after the first year (Figure 1).

Additional predictors

The risk of subsequent disability associated with gun injury was also related to patient characteristics. Lower socioeconomic status, an urban home location, a nighttime incident time and ambulance arrival were each associated with higher risks (Table 3). A past diagnosis of mental illness or of substance use disorder or a recent emergency department visit was also associated with higher risks. Conversely, patient age and sex were not significant predictors. The day of the week or the season were also not significant predictors. Adjustment for all measured patient characteristics suggested that intentional gun injury was associated with an increased risk of subsequent disability relative to unintentional gun injury (HR 1.40, 95% CI 1.24–1.60).

Secondary analyses

The higher relative risk of subsequent disability associated with intentional gun injury relative to those with unintentional gun injury extended to important subgroups. In particular, a higher risk was observed for patients treated and released from the emergency department and for patients admitted to hospital (Appendix 1B). Similarly, a higher risk was observed regardless of a history of mental illness, substance use disorder, firearm weapon type, ambulance involvement, health care in the prior year or length of hospital stay. A higher risk was consistent for incidents that were self-inflicted and for incidents from interpersonal assault. No subgroup showed contrary findings and all subgroups with more than 1000 patients showed a significant higher relative risk.

Subsequent mortality

The higher risks of subsequent disability associated with intentional gun injury were also observed for long-term mortality, although the absolute counts were modest (Figure 2). Patients surviving intentional gun injury accounted for 137 subsequent deaths, equal to an incidence of 8 per 1000 patients annually. Patients surviving unintentional gun injury accounted for 156 subsequent deaths, equal to an incidence of 4 per 1000 patients annually. Taken together, intentional gun injury was associated with an increased risk of mortality relative to unintentional gun injury (HR 1.85, 95% CI 1.47–2.33). Additional predictors of subsequent mortality included older age, lower socioeconomic status, an incident occurring at night and a diagnosis of mental illness (Table 3).

Interpretation

We studied gun injury to assess the long-term risks of disability. We found that most patients survived during the initial hospital stay and many later became disabled. The risk of long-term disability was substantial, amounting to more than 1 in 5 patients with intentional injuries and 1 in 10 patients with unintentional injuries. The higher relative risk of long-term disability following intentional gun injury was not fully explained by baseline patient demographic characteristics, occurred regardless of whether the incident was self-inflicted or from interpersonal assault, and extended to those who were not admitted to hospital. Taken together, these data suggest that mortality statistics underestimate the effects of gun injury because many patients do not lose their lives, but lose their livelihoods.[62,63]

Our study supports past reports of long-term outcomes after other forms of injury. A retrospective cohort study in a Baltimore population evaluated all adult trauma patients over

Table 1: Characteristics of 8313 patients with intentional or unintentional gun injury who received emergency medical care during the study period

Characteristic	No. (%) of patients	
	Intentional* *n* = 3020	Unintentional *n* = 5293
Demographic		
Age, yr		
< 30	1857 (61.5)	3178 (60.0)
≥ 30	1163 (38.5)	2115 (40.0)
Sex		
Male	2754 (91.2)	4756 (89.9)
Female	266 (8.8)	537 (10.1)
Home		
Urban	2759 (91.4)	4270 (80.7)
Rural	261 (8.6)	1023 (19.3)
Socioeconomic quintile†		
5 (highest)	250 (8.3)	705 (13.3)
4	356 (11.8)	853 (16.1)
3	517 (17.1)	1034 (19.5)
2	716 (23.7)	1067 (20.2)
1 (lowest)	1181 (39.1)	1634 (30.9)
Past year health care		
Hospital admission		
Yes	92 (3.0)	119 (2.2)
No	2928 (97.0)	5174 (97.8)
Emergency visit		
Yes	1087 (36.0)	2095 (39.6)
No	1933 (64.0)	3198 (60.4)
≥ 7 outpatient visits		
Yes	342 (11.3)	509 (9.6)
No	2678 (88.7)	4784 (90.4)
Substance use disorder diagnosis‡		
Yes	221 (7.3)	289 (5.5)
No	2799 (92.7)	5004 (94.5)
Mental health diagnosis§		
Yes	698 (23.1)	1086 (20.5)
No	2322 (76.9)	4207 (79.5)
Acute incident		
Weapon		
Hand gun	63 (2.1)	238 (4.5)
Long gun	25 (0.8)	422 (8.0)
Uncertain	2932 (97.1)	4633 (87.5)
Ambulance		
Yes	2055 (68.0)	1284 (24.3)
No	965 (32.0)	4009 (75.7)

Note: OHIP = Ontario Health Insurance Plan.
*Denotes self-inflicted (codes X6·, X7·, X80 - X84) or assault (codes X85 - X89, X9·, Y0·).
†Based on Statistics Canada algorithm.
‡OHIP diagnostic codes 303 to 304.
§OHIP diagnostic codes 290 to 316 (except 293, 294, 303, 304, 308, 310, 312).

Table 2: Acute hospital care in 8313 patients with intentional or unintentional gun injury who received emergency medical care during the study period

Characteristic	No. (%) of patients*	
	Intentional *n* = 3020	Unintentional *n* = 5293
Hospital admission		
Yes	1638 (54.2)	792 (15.0)
No	1382 (45.8)	4501 (85.0)
Surgical procedure		
Yes	1060 (35.1)	538 (10.2)
No	578 (19.1)	254 (4.8)
No admission	1382 (45.8)	4501 (85.0)
Critical care unit		
Yes	756 (25.0)	266 (5.0)
No	882 (29.2)	526 (9.9)
No admission	1382 (45.8)	4501 (85.0)
Blood transfusion†		
Yes	457 (15.1)	176 (3.3)
No	1181 (39.1)	616 (11.6)
No admission	1382 (45.8)	4501 (85.0)
Time in hospital		
No. of days, median (IQR)	6 (3–11)	5 (2–10)
No admission	–	–
Outcome‡		
Death	363 (12.0)	204 (3.9)
Alive	2657 (88.0)	5089 (96.1)

Note: IQR = interquartile range.
*Unless stated otherwise.
†Based on packed red cells, platelets or whole blood.
‡Excludes deaths at the scene and includes short-term emergency and hospital care.

10 years and found a 15% risk of hospital mortality after gun injury.[64] In contrast, the relatively lower 7% hospital mortality observed in our study may be partially attributable to a smaller number of intentional incidents with reduced injury severity. Additional studies of mortality spanning similar long-term follow-up show a comparable risk of long-term mortality despite the overall decline in hospital case fatality rates.[65,66] Readmissions for delayed complications are also commonly reported in case series analyses of patients after gun injury, with a majority occurring after the first year postdischarge.[62]

Systematic investigations of quality of life after gun injury are relatively sparse, typically based on small select samples, and tend to use qualitative survey responses. One study conducted by telephone interviews years after hospital discharge found that about half the patients had physical limitations and nearly two-thirds experienced psychological illnesses following gun injury.[67] The risks of long-term disability were further accentuated in patients of lower socioeconomic status.[68] These self-reported findings agree with the high prevalence of long-term disability observed in our study. To our knowledge, there are no systematic studies of long-term disability after gun injury in a Canadian population, and international literature repeatedly highlights the gaps in the scientific understanding of long-term outcomes for patients after gun injury.[69,70]

The uncertain reasons underlying long-term disability suggest the need for a multimodal approach to trauma survivorship.[71] This might include follow-up care from surgeons, psychiatrists, family physicians, physiotherapists, social workers, occupational therapists, spiritual care workers and other allied professionals.[72] Current clinical care does not abandon patients; however, our study suggests that the prevailing efforts are not sufficient. Future clinical priorities could include additional management of pain, depression, anxiety, sleep and substance use disorder.[73–75] Additional counselling might also be necessary for workforce participation, including a role for a navigator to negotiate between a disabled survivor and a potential employer.[76] To the best of our knowledge, no trauma centre offers such a holistic follow-up clinic for adults after gun injury.[77,78] Our study highlights a substantial need to support survivors.[79]

Future research based on additional data sources might be justified as opportunities to address these and other uncertainties.[80,81] These studies might include broad surveys of clinical treatments and unmet health care needs over time.[82] An alternative approach can be an evidence-based social network analysis of social dynamics among survivors over time.[83] Further investigations might examine specific risk factors for gun injury and predictive factors for recovery outcomes.[84] A more controversial line of study can test the subjective nature of disability and the fallible determinations of severity.[85] Additional opportunities might also include analyses of governmental and consumer databases from other countries.[86]

Limitations

Our study has many limitations. The patients were mostly injured in isolated incidents and this provides little insight about gang violence or mass casualty events.[87–89] The data were based on a large high-income region and may underestimate losses in low-resource settings. Our data may also underestimate losses owing to fallibility in identifying intentional injuries.[3] The study does not account for patients who died at the scene, those who moved away (and were assumed fine) or those harmed by a culture of fear.[70,90] Disability data may also underestimate additional losses from missed days at work, career advancement, family relationships, emotional distress, trauma recidivism and financial costs.[91,92] The design was an observational analysis and cannot establish whether a correlation indicates possible causality (E-value = 2.80).[93–96]

The findings may be also prone to misquotation in public debates about firearms.[97] Specifically, the observed risks of long-term disability do not directly prove or disprove calls for gun control.[98] The study does not address safe storage, background checks, licensing policies, waiting periods, safety training or other particular injury prevention strategies.[99,100]

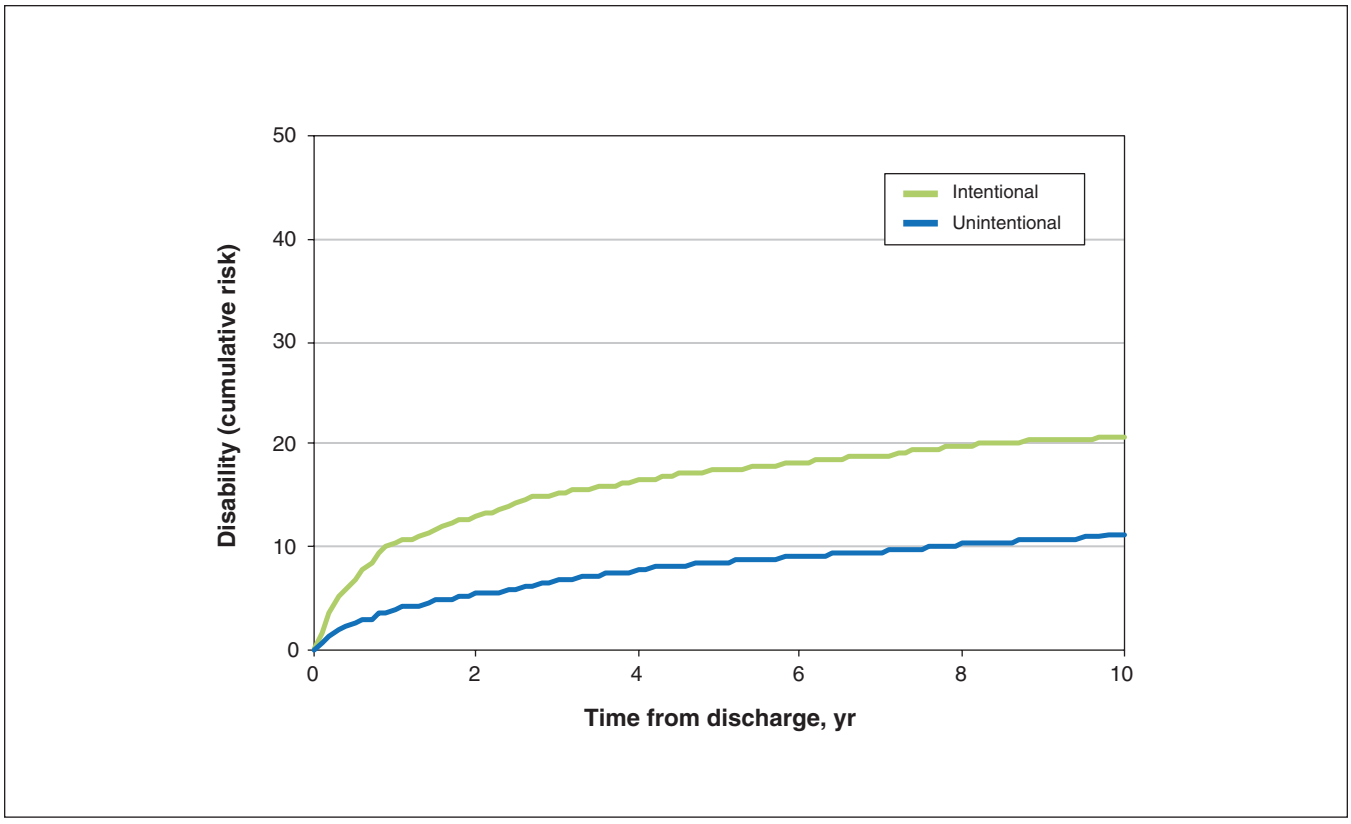

Figure 1: Risk of subsequent disability. Cumulative incidence plots of absolute risk of disability following injury.

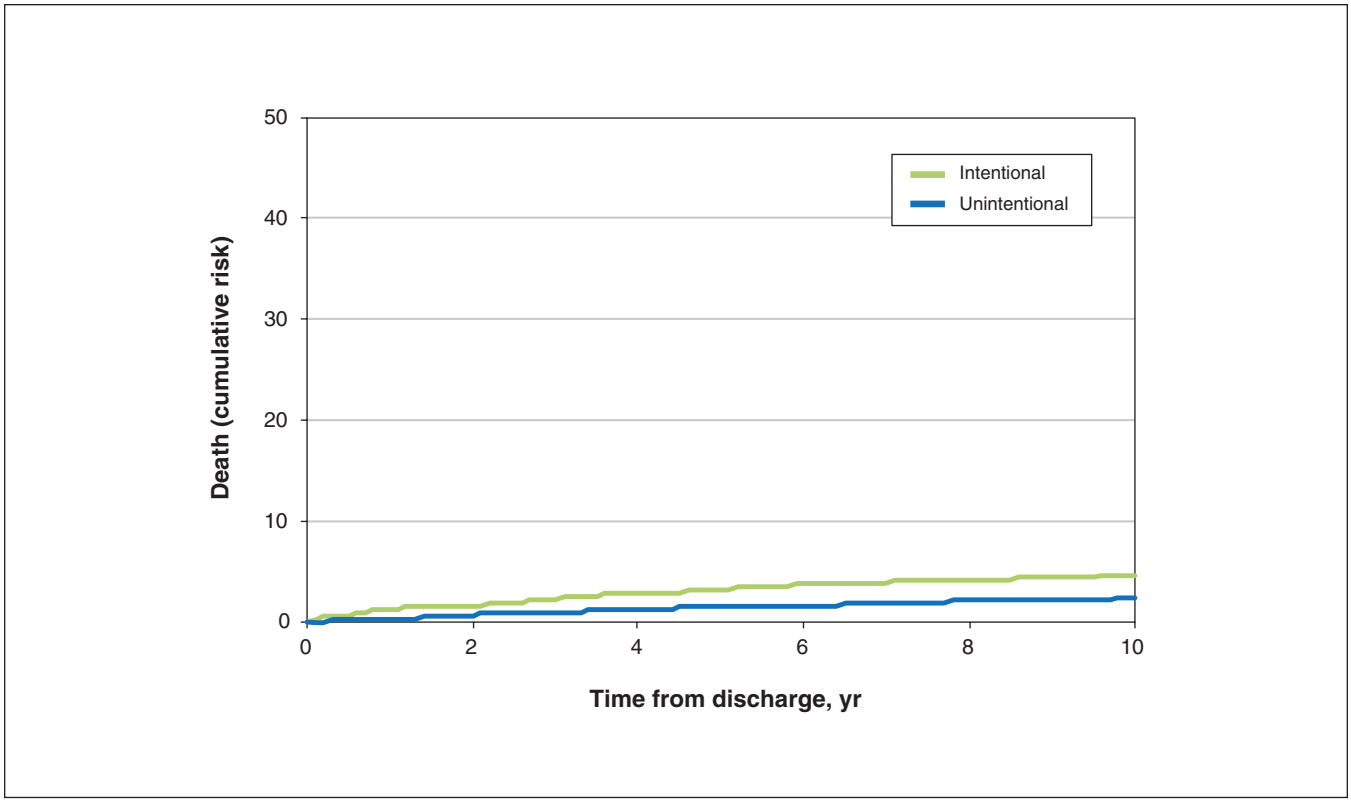

Figure 2: Risk of subsequent death. Cumulative incidence plots of absolute risk of death following injury.

Table 3: Predictors of disability after gun violence*

Characteristic	Relative risk (95% CI)	
	Basic analysis†	Adjusted analysis‡
Acute injury		
Intentional injury	2.01 (1.80–2.25)	1.40 (1.24–1.60)
Age group		
Younger (Ref. ≥ 30 yr)	0.96 (0.85–1.07)	§
Sex		
Male	0.95 (0.79–1.14)	§
Home location (Ref. = rural)		
Urban	1.86 (1.54–2.25)	1.48 (1.22–1.80)
Socioeconomic quintile (Ref. = middle)		
Highest	0.81 (0.67–0.98)	0.86 (0.70–1.04)
Lowest	1.52 (1.30–1.78)	1.39 (1.19–1.63)
Incident season (Ref. = summer)		
Autumn	0.91 (0.79–1.06)	§
Winter	1.05 (0.90–1.24)	§
Spring	1.04 (0.89–1.21)	§
Incident day (Ref. = weekday)		
Weekend	1.07 (0.95–1.20)	§
Incident hour (Ref. = afternoon)		
Morning	1.09 (0.92–1.28)	1.03 (0.87–1.22)
Night	1.32 (1.17–1.50)	1.08 (0.95–1.23)
Ambulance transport		
Yes	2.21 (1.98–2.47)	1.76 (1.55–1.99)
History		
Hospital admission in past		
Yes	1.33 (0.90–1.95)	§
Emergency visit in past		
Yes	1.23 (1.10–1.38)	1.16 (1.03–1.31)
Outpatient visits in past		
Count	1.02 (1.02–1.03)	1.01 (1.00–1.01)
Mental health diagnosis in past		
Yes	1.92 (1.70–2.17)	1.67 (1.47–1.91)
Substance abuse in past		
Yes	2.43 (2.04–2.89)	1.62 (1.32–1.99)

Note: CI = confidence interval, Ref. = referent.
*Estimates based on Fine and Gray model. Analyses based on all patients surviving acute gun violence.
†No adjustment for baseline differences.
‡Adjusted for all measures significant in univariable analysis.
§Denotes estimates not significant in univariable or multivariable model.

The analysis provides no data on the benefits of gun ownership for those who gain security and experience no adverse incidents.[101] The specific data on determining firearm type are difficult to interpret because of the large number of cases with missing information. The research cannot settle the unceasing tension between safety and liberty because moral imperatives extend beyond a biomedical perspective.[102–104]

An additional caveat is that our data do not explain mechanisms by which gun injury might lead to higher disability after intentional rather than unintentional incidents. Many

biomedical and social factors could contribute to these mechanisms including severity of injury, preexisting illnesses and background community supports.[105–108] Another potential contributor is the fear of being labelled from identifying as a victim, which may lead to reduced self-esteem, decreased self-efficacy and depression.[75,109–111] A further possibility may be the nature of blame, concepts of responsibility and a negative spiral of disempowerment with anxiety.[112–114] A different explanation might be a statistical artifact from fallible ascertainment of intent leading to misclassification bias.

Conclusion

Gun inujury causes considerable mortality yet many patients survive with long-term disability. The long-term risks of disability are particularly accentuated for survivors after intentional injuries.

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